

Bird Study

ISSN: 0006-3657 (Print) 1944-6705 (Online) Journal homepage: www.tandfonline.com/journals/tbis20

Radar reveals the nocturnal flights of breeding Grey Gulls *Leucophaeus modestus* in the Atacama Desert, Chile

Carlo Catoni, Roberto Aguilar-Pulido, Carlos Zavalaga & Giacomo Dell'Omo

To cite this article: Carlo Catoni, Roberto Aguilar-Pulido, Carlos Zavalaga & Giacomo Dell'Omo (2021) Radar reveals the nocturnal flights of breeding Grey Gulls *Leucophaeus modestus* in the Atacama Desert, Chile, Bird Study, 68:3, 351-358, DOI: 10.1080/00063657.2022.2092067

To link to this article: https://doi.org/10.1080/00063657.2022.2092067

Published online: 05 Jul 2022.

Submit your article to this journal

Article views: 512

View related articles

View Crossmark data

Citing articles: 1 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tbis20

BIRD STUDY
2021, VOL. 68, NO. 3, 351–358
https://doi.org/10.1080/00063657.2022.2092067

Check for updates

Radar reveals the nocturnal flights of breeding Grey Gulls *Leucophaeus modestus* in the Atacama Desert, Chile

Carlo Catoni [a], Roberto Aguilar-Pulido[b], Carlos Zavalaga [c] and Giacomo Dell'Omo[a]

[a]Ornis italica, Rome, Italy; [b]Corporación Cultam, Antofagasta, Chile; [c]Unidad de Investigación de Ecosistemas Marinos – Grupo Aves Marinas, Universidad Científica del Sur, Lima, Peru

ABSTRACT

Capsule: Grey Gulls *Leucophaeus modestus* breed in the Atacama Desert, Chile, and perform nocturnal commuting flights between their inland nesting sites and the coast in order to forage. Some aspects of the gullś flight patterns and routes remain unknown.

Aim: Determine the patterns and the routes of the commuting flights of Grey Gulls breeding in a remote colony in the Atacama Desert.

Methods: Using a modified marine radar we tracked the departure and arrival times, and direction of Grey Gulls. Furthermore, we managed to ground truth the information obtained from the radar by tracking two incubating gulls with GPS tags.

Results: Birds left the colony in two waves: first between 21:00 and 22:00 at the onset of nautical twilight, and a second, larger wave between 02:00 and 05:00 (peak at 03:15) before sunrise. Birds returned to the colony through the whole night with a major peak at 23:00, two hours after sunset. Tracking data confirmed the travel times and directions obtained from the radar.

Conclusion: Grey Gulls adjust their departure time from the colony and from the coast to fly only in the dark. Most birds left just after nautical twilight and flew at a constant speed to the coast. By knowing the arrival time, the peak of bird passage and their inbound flying direction, it is possible to infer the location of the departure place on the coast. By identifying consistent inbound flight patterns with radar it is possible to detect unknown colonies.

ARTICLE HISTORY
Received 15 March 2021
Accepted 21 October 2021

The study of flight behaviour of nocturnal animals, such as bats and birds, has always faced obvious difficulties. Many species are suitable for tracking with global positioning system (GPS) devices to examine individual-based movement behaviour, but the assessment of nocturnal flight routes of large groups of commuting animals is more challenging and radar is currently the only available tool. Thermal imaging cameras might seem a convenient alternative but do not provide enough resolution, particularly at large distances. Radar has been used to study bird movement for the last 70 years (Gauthreaux & Belser 2003) but only in recent years has it been used to monitor colonial seabirds, especially Procellariformes, when returning to their colonies at night (Bertram *et al.* 1999, Day & Cooper 1995). While many seabirds breed in marine locations that are difficult for predators to access, such as islands or sea-cliffs, a few species have evolved to breed in the driest and most remote deserts on Earth, such as the Atacama Desert, in northern Chile.

The Grey Gull *Leucophaeus modestus* breeds in the interior of the Atacama Desert, up to 120 km from the coast, and performs daily commuting trips to the coast for foraging (Howell 1982, Fitzpatrick *et al.* 1998). Rare, occasional nesting has also been reported on coastal beaches (Aguilar *et al.* 2016). Grey Gulls are globally categorized as Least Concern by the International Union for Conservation of Nature (IUCN), despite a population decrease and few known colonies (IUCN 2018). However, Grey Gulls are considered Vulnerable in Chile (Decreto Supremo No. 16/2020, Ministerio del Medio Ambiente, Chile).

Grey Gulls exhibit some breeding behaviours that are unique among gulls, and which are not fully understood. During incubation and early brooding, one member of the pair remains in the nest throughout the day while its partner forages. Partners invariably swap during the night, relieving birds from incubating or brooding duty so they can forage. Only a few untested hypotheses have been proposed to explain this behaviour, such as the avoidance of

CONTACT Carlo Catoni carlo.catoni@gmail.com
© 2022 British Trust for Ornithology

diurnal predators (Howell *et al.* 1974, Howell 1982). Despite the remoteness of their breeding sites, flying at night over the desert may be an increasingly risky activity for Grey Gulls, as an increasing amount of new structures are being built or planned in the Atacama Desert to provide alternative energy sources to the mining industry. In particular, wind farms and power lines can prove fatal for birds commuting at night, when the risk of collision is higher. Understanding the movement patterns of Grey Gulls can help determine their flight corridors over the desert, knowledge of which is critical to protect this localized species from future industrial development. This study may serve as a template for studies of other seabird species breeding in the Atacama Desert, such as Markham's Storm Petrel *Oceanodroma markhami* and Ringed Storm Petrel *Hydrobates hornbyi*, whose nocturnal flight behaviours are entirely unknown.

In this study, we used a marine radar in the periphery of a large Grey Gull colony in northern Chile to monitor the nocturnal movements in the desert. Specifically, we aimed to: (1) reveal incoming and outgoing flight routes and (2) determine flight direction, speed and altitude. In addition, we compared the radar data with that gathered from GPS tracking tags deployed on birds at the same colony.

Methods

Study area

Fieldwork was carried out in a colony called Cerro Chanchito, 28 km east of Quillagua, northern Chile (21.65° S 69.53° W, Figure 1). The colony was approximately 80 km from the nearest point on the coast and extended over a surface of about 3.7 km^2 in a flat elongated area at the foot of a series of small hills. The colony held approximately 30,000 pairs of Grey Gulls in 2016–2017 (Aguilar *et al.* 2016). Fieldwork with radar and GPS tags in the colony was carried out between 17 and 24 January 2017. We initially deployed the radar at the periphery of the colony (Radar Site 1, Figure 1) for three days, then moved to a second location (Radar Site 2, Figure 1) to the west, to monitor gull passage further from the colony.

Radar observations

We detected the movement patterns of Grey Gulls using a modified GEM SuperNet (9410 MHz, 10 kW) marine radar (GEM *elettronica*, Italy) with a 2.1 m rotating antenna (38 revolutions per minute) powered by two 12 V DC batteries in series (24 V DC in total). The radar was placed on a tripod about 2 m above the ground, with unobstructed views over the colony and over the western, southern and northern flyways to and from the colony. The topography of the area allowed for good visibility all around the colony, and did not require any anti-clutter screen nor software filter. The radar was set to have a 2 km radius and its centre was slightly moved southeast, extending its effective range to the north and west of the colony. The radar scale still allowed us to see single birds flying to and from the colony and at the same time to monitor the movement of birds up to 3 km.

Data were collected for three nights between 17 and 20 January 2017 at Radar Site 1 and for two nights, from 20 to 24 January 2017, at Radar Site 2 (Figure 1). Considering the remoteness and the logistic difficulties, we considered that this period was long enough to gather sufficient data. Radar Site 1, located at the western margin of the colony, was selected to detect aerial traffic of the birds at the colony border and reveal arrival and departure times of individuals in more detail. The antenna was set to rotate horizontally thus enabling us to measure speed, trajectories and direction of birds. The area covered by the radar, however, did not cover the entire colony but only a portion with an undetermined number of pairs. Radar Site 2 was 24 km away from the colony, again on the western side, between the colony and the coast, and was selected to intercept the commuting flights and reveal the flying patterns over the desert and, possibly, detect birds moving towards other directions (i.e. moving towards other unknown colonies). The radar was operated at night from 21:00 to 06:20 of the following day. At Radar Site 2, the radar was operated with the antenna rotating horizontally (as at Radar Site 1) on the first night, while on the second night the radar antenna was set to rotate vertically, to monitor flight altitudes up to 1.2 km.

Radar data analysis

The screen of the radar with the moving echoes was recorded continuously with Debut Video (NCH Software). Birds required between 3 and 6 min to cross the whole radar screen and we counted all birds on screen arriving to and leaving the colony every 10 min. This avoided double counting but may have caused underestimation of the number of commuting birds. By measuring the time interval required to fly a known distance (measured on the radar scale) it was possible to calculate speed and direction for 100

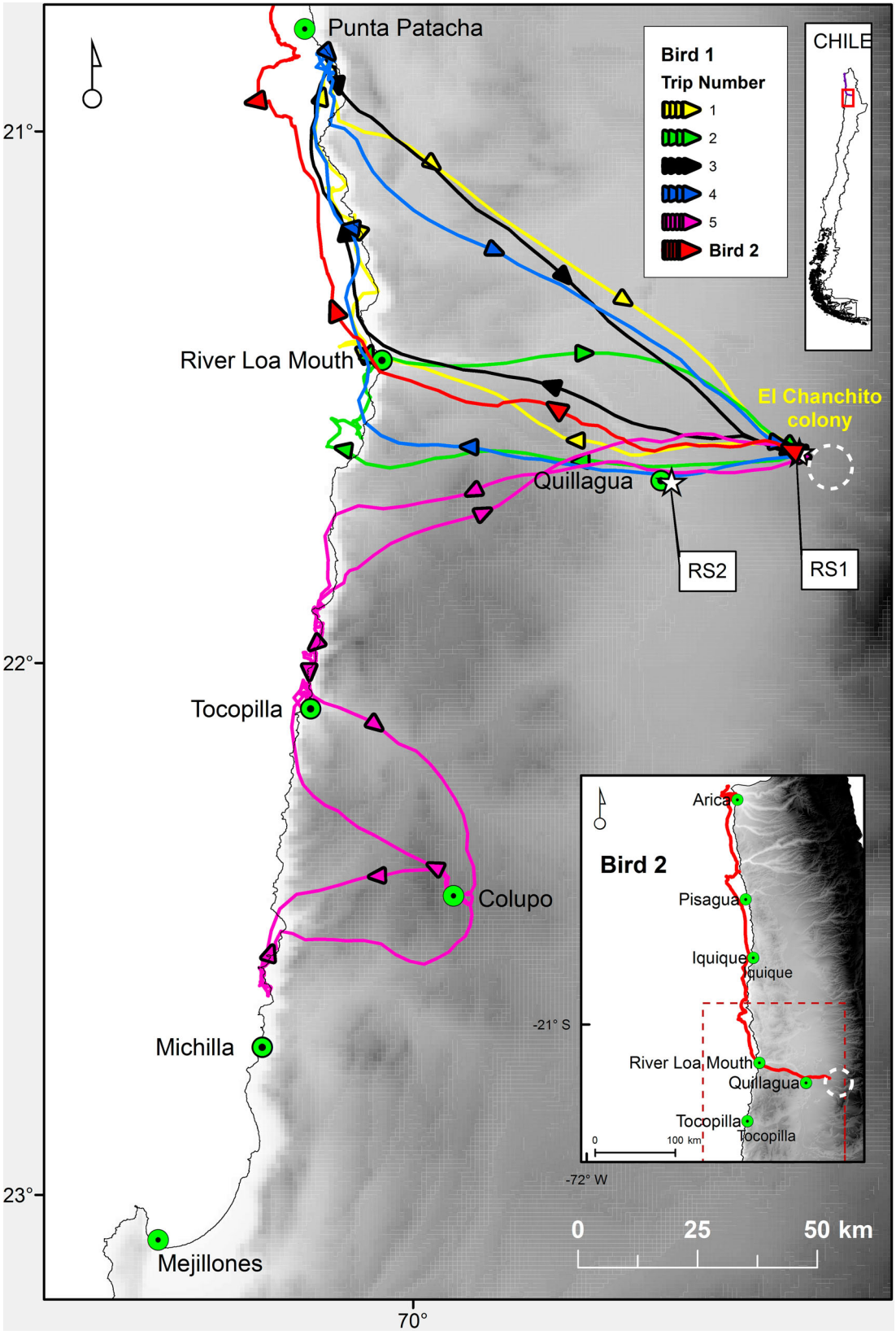


Figure 1. Study area and GPS tracks of the two tracked birds. The figure shows the study area, located in northern Chile, the colony Cerro El Chanchito with the Radar Site 1 (RS1) and Radar Site 2 (RS2) located closer to the town Quillagua. The tracks of the first bird marked with a GPS tag are shown with a different colour for each trip from and to the colony. The second bird is represented in red and travelled north up to Arica, as shown in the small box.

individuals flying towards the colony and 100 leaving the colony. We selected trajectories of individuals with an index of straightness higher than 0.9. Straightness is defined as the ratio between the straight distance between its ends and the total length of the track. Mean and standard deviations of flight directions were calculated using circular statistics (Batschelet 1981).

GPS tracking

To extend our knowledge about the movements of foraging Grey Gulls when they moved out of the range of our radar, we caught two incubating birds at their nests with remotely triggered leg loops and deployed GPS tracking units with remote data download (Gipsy Remote, Technosmart Europe, Rome, Italy). GPS tags were fitted to the birds with a leg loop harness of Teflon-ribbon (6.5 mm Bally Ribbon, USA). To reduce the impact of trapping, true eggs were replaced with dummy eggs during capture operations. The GPS tags weighed 10 g, which was 2.8% of the tagged birds' body weight (approximately 350 g). The GPS tags included solar panels which allowed them to recharge during the day and record at a rate of one fix every 5 min during night and day. The devices are connected via ultra-high frequency (UHF) radio to an automatic base station. This allowed data from the units to be downloaded remotely whenever the devices were within 1 km of the base station. Flight directions, movements and inbound/outbound flight speeds were calculated from the GPS fixes.

Results

Grey Gulls are the only gregarious species of their size flying at night within the monitored area, so we are confident that radar signals corresponded to Grey Gulls. In fact, the only other birds which could be encountered in such habitat are the Hornby's Storm Petrel and the Markham's Storm Petrel, colonies of which have been observed far from the coast into the Atacama Desert (Barros *et al.* 2018, Barros *et al.* 2019). These species were detected in very small numbers by the radar in Radar Site 2, and were easily distinguished by their much smaller echoes allowing us to exclude them from the analysis.

Pattern of movements

Radar Site 1: colony border

During the three nights at Radar Site 1, the pattern of movements was relatively constant, with most birds leaving on foraging trips in one of two waves: the first right after the onset of nautical twilight (with a peak at 21:30, the onset of astronomical twilight) and the second at the end of the night (peak between 3:00 and 3:30). Birds arrived at the colony throughout the night, but the peak of arrivals started 2 h after sunset and lasted for over an hour (between 22:50 and 00:00, Figure 2).

We counted a mean of 7054 gulls leaving the colony each night, and a mean of 7781 gulls returning. There are a few possible explanations for this discrepancy. First of all, it should be borne in mind that the radar did not extend to the whole colony, so it might have not detected a few hundred birds leaving a part of the colony outside its range. It is also possible that some non-breeding birds travelled to and from the colony less regularly, which could result in a discrepancy over a period of just three days. Finally, we cannot exclude that by counting birds every 10 min we just missed birds leaving the colony.

The mean (± SD) flight speed of birds arriving to the colony was 44.3 ± 5.76 km/h while those leaving flew slightly slower, at 39.6 ± 6.4 km/h. The mean (± SD) direction of birds arriving to the colony was 325 ± 12.5° while that of departure flights was 290 ± 11.3°. The latter is very close to the direction of the shortest route to the sea, at about 85 km. The returning direction, on the other hand, showed that birds were flying back from a more northerly location along the coast. At the average recorded flight speed, departing gulls would require slightly more than 2 h to reach the sea if they were flying at constant speed and direction for the whole trip.

Radar Site 2: 24 km west of the colony

At Radar Site 2, we monitored the movements of gulls for two nights. The first night, with the radar antenna rotating horizontally, we detected 457 birds flying in the direction of the colony and 1033 towards the sea. This is consistent with the movement patterns described above. The second radar location lay approximately on the average flight line of birds departing the colony for the coast but was south of the line taken by most returning birds.

The second night, with the radar antenna rotating vertically, we were able to measure flight altitude up to 1200 m above ground level. We counted 425 birds, 80% of which were between 60 and 660 m above the ground (Figure 3). Only about 4% of detected birds were within 60 m of the ground, with the remaining birds being evenly distributed between 660 and 1200 m.

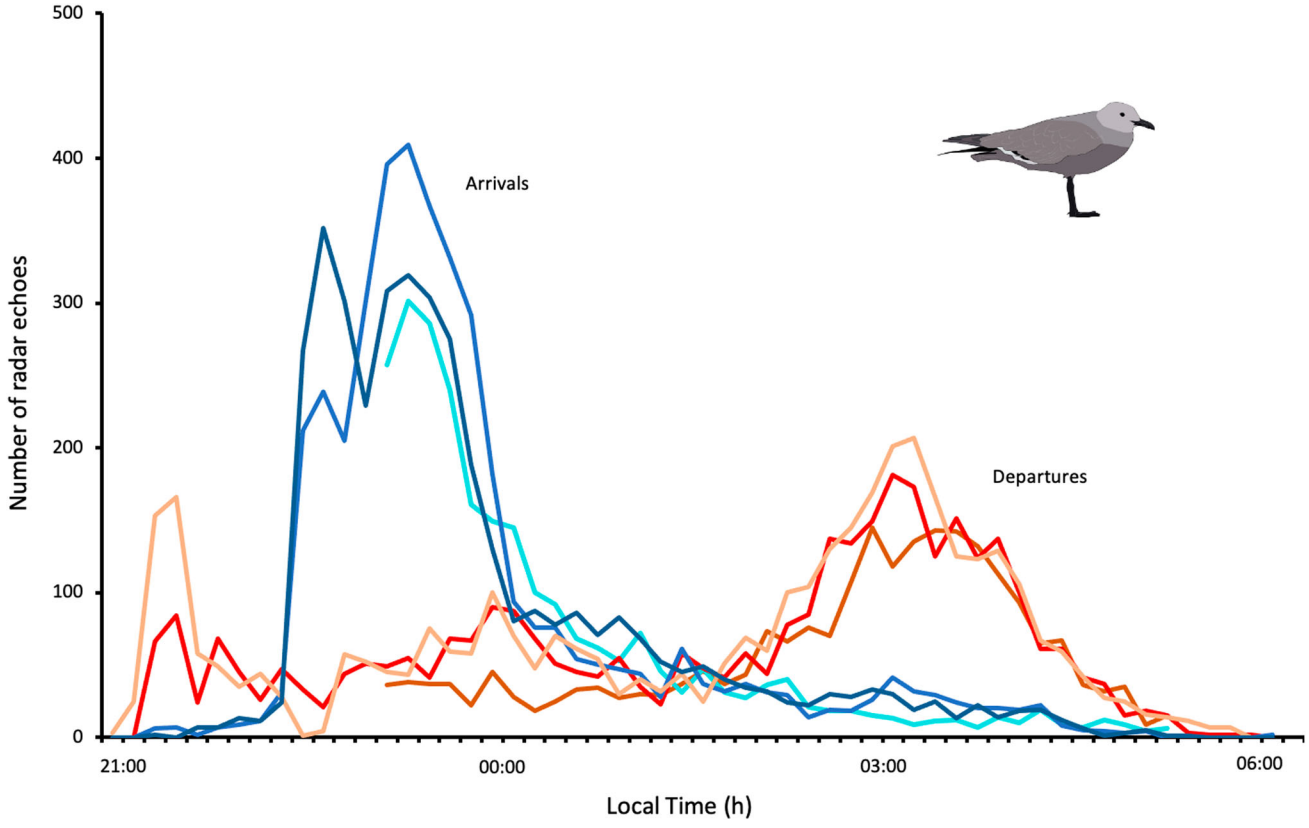


Figure 2. Arrival and departure time from the colony at Cerro Chanchito as detected by the radar. The arrival of the birds (blue tones) peaked in the late evening, while the departures (red tones) started at sunset but continued the whole night, peaking two hours before sunrise.

GPS tracking

The two birds (Bird 1 and Bird 2, Figure 1) tracked with GPS tags left the breeding colony one or two days after the attachment of the devices and only Bird 1 returned to the colony (Figure 1). GPS data of Bird 2 was downloaded on the coast at 87 km north of Tocopilla a few days after nest desertion. Although handling time was kept to a minimum, we cannot exclude that breeding failure was caused by our manipulation or the discomfort caused by the harness and the device. However, we cannot rule out nest predation either, as we recorded a high rate of nest predation by Turkey Vultures *Cathartes aura* in the area.

Based on the GPS fix patterns, Bird 1 returned five times to the colony after completing five looping trips to the coast (Figure 1). However, the bird remained only between 1.5 and 3.5 h near the nest before departing again, indicating desertion of the nest. In these trips, Bird 1 arrived at the colony between 02:00 and 04:00, and departed from the colony between 05:40 and 06:30. The outbound tracks of both birds matched with good approximation the departure bearings observed with the radar. Both birds started to leave the colony in the direction of the shortest path to the sea, and usually travelled north along the coast during the day. Bird 1 flew back to the colony preferentially from the northwest. After the fourth trip, Bird 1 visited another area not far from the abandoned colony called Colupo (Figure 1). On that occasion, the bird flew southwest before returning to Cerro Chanchito.

The mean (± SD) flight speed of Bird 1 over the desert in the last 30 km before arriving to the colony was 47.9 ± 7.2 km/h while its speed in the first 30 km after leaving the colony was 40.7 ± 6.8 km/h. Overall, mean flight speed over the desert was 39.2 ± 4.7 km/h. Interestingly, given the rather consistent departure time of the tracked individual from the coast (in 7 days it departed always within 20 min of the onset of the astronomical twilight), arrival time at the colony was highly correlated with distance travelled (linear fit, $R^2 = 0.88$, $n = 7$, $P < 0.005$). Finally, when leaving the colony, Bird 1 crossed the area of the second radar site three times, with a mean (± SD) height above the ground of 270 ± 85 m, measured from GPS altitude.

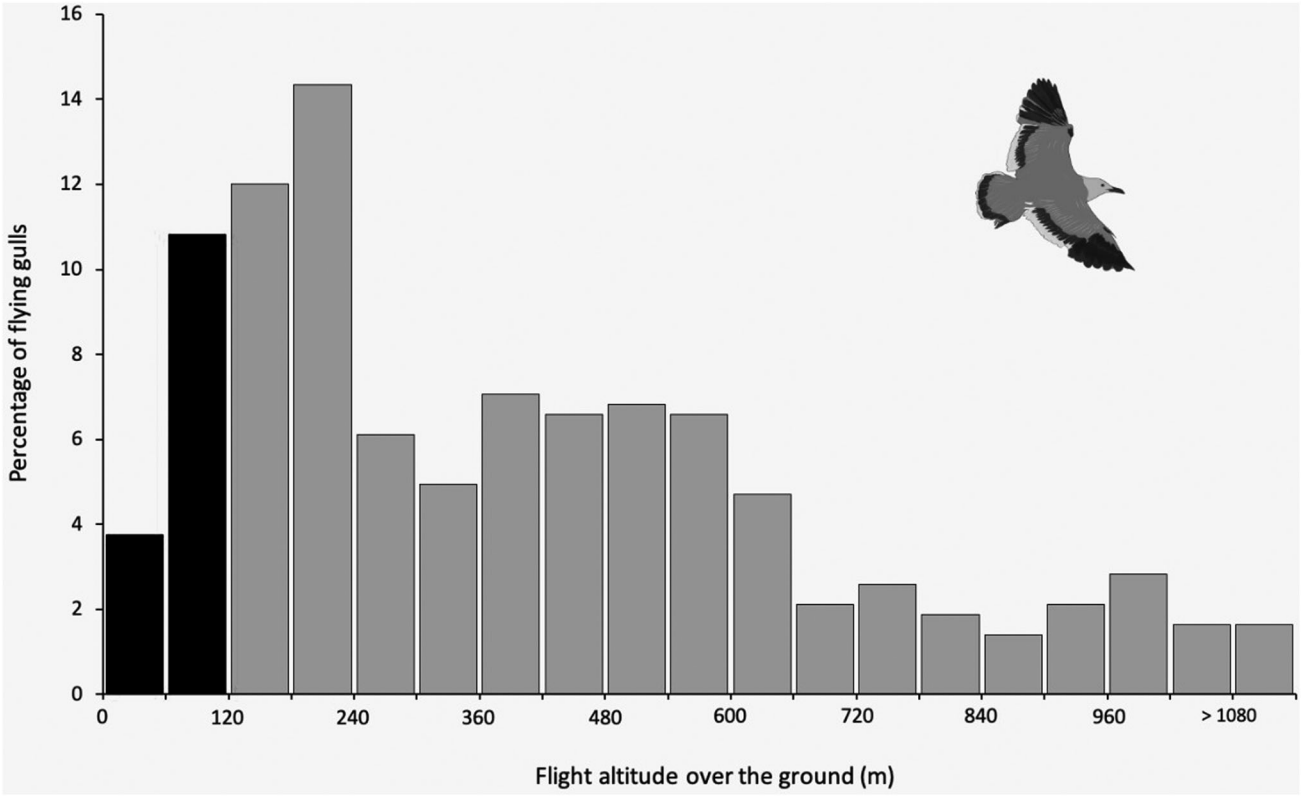


Figure 3. Flight altitude of Grey Gulls at the Radar Site 2. In black are shown the percentage of birds which would be in the height of a planned wind farm close to the study area. Most of the birds flew within 240 m of the ground, but a few birds were detected higher than 1000 m.

Discussion

Patterns of departure and arrival at the colony are useful information for seabird ecologists because they may help to better understand foraging strategies and time budgets in the breeding season. However, these movements can be challenging to determine in nocturnal species (Reynolds *et al.* 1997). The Grey Gull performs its foraging trips between the colony and the sea strictly at night and therefore detailed aspects of its nocturnal movements remain unknown.

In this regard, the Grey Gull is probably a unique species among gulls, being a diurnal forager but commuting to the colony only at night (Howell 1974). This pattern is shared with several species of shearwaters and storm petrels, which return to the colony only at night (Dell'Ariccia & Bonadonna 2013). In Grey Gulls, this behaviour could have evolved for a variety of reasons, including: (i) predatory avoidance, (ii) to avoid the hottest hours of the day and (iii) to reduce energy costs by taking advantage of the night winds (Fitzpatrick *et al.* 1988).

The peak interval of arrivals to the colony lasted about 1.5 h (from 22:50 h to 00:30 local time), when 77% of the birds arrived at the colony, mainly from the northwest. This peak was about 1.5 h after the onset of nautical twilight (around 21:30) and closely resembled the returning pattern of Procellariformes to their colonies (Day *et al.* 2003). This is not surprising, considering that the majority of gulls leave the sea after the onset of twilight and need roughly two hours of flight to travel the 85 km from the sea to the colony. Assuming the departure time at around 21:30 on the coast, as shown from the GPS data, and considering an average flight speed of 40.8 km/h, we calculated that the majority of birds departed from a location between 85 and 117 km from the colony. Interestingly, the gull monitored with the GPS spent several days foraging in an area at sea placed exactly at 120 km from the colony in the north (Figure 1). Based on the speed measured by GPS and radar it would be possible to identify the approximate location on the coast (supposedly close to their foraging grounds) from where most gulls started their return trip, therefore determining their main foraging grounds.

From our radar and GPS observations, it is apparent that the Grey Gulls regulate departure from the colony in order to avoid flying over the desert in daylight, as already suggested by Howell (1982). In this regard, Grey Gulls are similar to most shearwater and petrel

species, which avoid returning to their colonies before complete darkness (del Hoyo *et al.* 1992), probably to reduce predation risk (Mougeot & Bretagnolle 2000, Rubolini *et al.* 2014). It is not known whether colony attendance of Grey Gulls is affected by moonlight, as is the case for most shearwaters (Mougeot & Bretagnolle 2000).

Gulls left the colony in two main periods: a minority of them right after the start of the nautical twilight, and a large majority in the second part of the night. The first peak might be associated with the departure of birds which have lost their nest to predators, or possibly with very hungry birds which cannot wait for the return of their partner. The rest of the birds left more or less constantly during the rest of the night until 04:30. This is again in accordance with the estimation of about 2 h to fly to the sea and the urge to reach it before the end of complete darkness (06:48 local time). In petrels breeding close to the sea, departure is usually around the end of complete darkness, because they do not need to fly long distances to reach the comparative safety of the sea (Day & Cooper 1995).

The main departure direction was toward the shortest distance to the coast, located approximately 85 km from the colony. Most birds returning to the colony, however, arrived from a more northerly location. This pattern was shown also by the two birds tracked with GPS tags, which reached the sea at roughly the closest point from the colony, then moving north to forage along the coast in the area between the mouth of River Loa and the town of Pabellón de Pica. On two occasions, one of these birds headed south toward the coastal town of Tocopilla. We visited this area shortly after and found an occupied colony with a few thousand Grey Gulls. Probably, after arriving at the coast using the shortest route, the birds moved north or south along the coast toward the best foraging areas. At dawn they started to return to the colony from their last foraging area, crossing the desert in an almost straight line. Unfortunately, our period of tracking was quite short and further investigation is required to understand the general patterns of desert crossing in this species.

At Radar Site 2 we recorded not only flight speed and direction but also altitude, which provided us with more information about bird movements in the desert. Most birds flew through the area at an altitude between 60 and 600 m above the ground, with the majority between 60 and 240 m. These birds would be at risk of collision with turbines if there was a wind farm in the area (Cook *et al.* 2012). The need to build new structures for energy production, such as big wind plants (e.g. The Andes Renovables Project by Mainstream Renewable Power), and infrastructure for mining activities in the Atacama Desert will raise important conservation issues for Grey Gulls in the coming years, particularly because the location of the breeding colonies can vary between years. Therefore, mitigating actions should not be restricted to site-specific measures, but should consider an understanding of the nocturnal flight patterns of the species across a variety of landscapes.

In this study, we demonstrate that radar is an efficient and cost-effective tool to monitor nocturnal movements of a large number of birds at the same time, determining patterns at the colony level, something which would not be possible with individual-based GPS tracking. Radar can determine more accurately the movement behaviour of a large proportion of birds in the colony, arrival and departure rates and flight altitudes (Day *et al.* 2003). All these parameters are important for a better understanding of the movement ecology of a species and the threats it may face. Furthermore, the use of radar is non-invasive and thus the birds have no detrimental effects from capture and tagging, and at the same time data has been shown to be reliable and representative of the behaviour of a large and undisturbed population of birds.

An important result for the ecology of Grey Gulls is that the arrival time at the colony of the GPS-tracked bird correlated with the distance travelled. Therefore, by knowing the arrival time of the birds at a colony it would be possible to estimate which areas on the coast are relevant feeding grounds for the birds.

The Grey Gull is facing a population decline (IUCN 2018) in Chile, yet our understanding of the ecology and behaviour of the species is limited. Also, there are emerging threats both at sea and on the breeding grounds which are not fully known by conservation agencies. For example, in addition to the dramatic predation of chicks and eggs by dogs at the coastal colonies (Aguilar *et al.* 2016) we noticed heavy predation by Turkey Vultures at colonies in the desert. During our field work we counted dozens of Turkey Vultures patrolling the colony in groups in search of eggs or chicks. They are probably attracted to the desert by an increased number of human settlements related to mining activities (Torres-Mura *et al.* 2015). Another major problem is the lack of data on the number and location of breeding colonies.

We have demonstrated that radar is a useful tool to tackle this issue and future work should be planned to discover new colonies and gather more information on the size of the breeding population and the flight patterns of Grey Gulls and potentially other seabird species in the Atacama Desert.

Acknowledgements

We thank Marietta Perucci for the help and support during field work.

Funding

The fieldwork was supported by *Ornis italica* and Minera Escondida Limitada, Minera Antucoya and Minera Sierra Gorda SCM through Act D.L. N° 3063 of donations for scientific purposes.

ORCID

Carlo Catoni http://orcid.org/0000-0001-8355-2529
Carlos Zavalaga http://orcid.org/0000-0003-1712-7334

References

Aguilar, R., Simeone, A., Rottmann, J., Perucci, M. & Luna-Jorquera, G. 2016. Unusual coastal breeding in the desert-nesting Gray Gull (*Leucophaeus modestus*) in northern Chile. *Waterbirds* **39:** 69–74.

Barros, R., Medrano, F., Norambuena, H.V., Peredo, R., Silva, R., de Groote, F. & Schmitt, F. 2019. Breeding phenology, distribution and conservation status of Markham's Storm-Petrel *Oceanodroma markhami* in the Atacama Desert. *Ardea* **107:** 75–84.

Barros, R., Medrano, F., Silva, R. & de Groote, F. 2018. First breeding site record of Hornby's Storm Petrel *Oceanodroma hornbyi* in the Atacama Desert, Chile. *Ardea* **106:** 203–207.

Batschelet, E. 1981. *Circular Statistics in Biology*. Academic Press Inc, San Francisco, CA.

Bertram, D.F., Cowen, L. & Burger, A.E. 1999. Use of radar for monitoring colonial burrow-nesting seabirds. *J. Field Ornithol.* **70:** 145–157.

Cook, A.S.C.P., Johnston, A., Wright, L.J. & Burton, N.H.K. 2012. A review of flight heights and avoidance rates of birds in relation to offshore wind farms. Strategic Ornithological Support Services. BTO Research Report Number 618.

Day, R.H. & Cooper, B.A. 1995. Patterns of movement of Dark-rumped Petrels and Newell's Shearwaters on Kauai. *Condor* **97:** 1011–1027.

Day, R.H., Cooper, B.A. & Blaha, R.F. 2003. Movement patterns of Hawaiian Petrels and Newell's Sheatwaters on the Island of Hawai'i. *Pac. Sci.* **57:** 147–159.

del Hoyo, J., Elliott, A. & Sargatal, J. 1992. *Handbook of the Birds of the World. Vol. 1. Ostrich to Ducks*. Lynx Edicions, Barcelona.

Dell'Ariccia, G. & Bonadonna, F. 2013. Back home at night or out until morning? Nycthemeral variations in homing of anosmic Cory's shearwaters in a diurnal colony. *J. Exp. Biol.* **216:** 1430–1433.

Fitzpatrick, L.C., Guerra, C.G. & Aguilar, R.E. 1988. Energetics of reproduction in the desert nesting seagull *Larus modestus*. *Estud. Oceanol.* **7:** 33–39.

Gauthreaux, S.A. & Belser, C.G. 2003. Radar ornithology and biological conservation. *Auk* **120:** 266–277.

Howel, T.R. 1982. Desert-nesting sea gulls. *Nat. Hist.* **91:** 52–59.

Howell, T.R., Araya, B. & Millie, W.R. 1974. *Breeding Biology of the Gray Gull, Larus Modestus*. University of California Publications in Zoology. Vol. **104**, pp. 1–57.

IUCN. 2018. The IUCN red list of threatened species. Version 2018-2. http://www.iucnredlist.org. Accessed 15/10/2018.

Mougeot, F. & Bretagnolle, V. 2000. Predation risk and moonlight avoidance in nocturnal seabirds. *J. Avian Biol.* **31:** 376–386.

Reynolds, M.H., Cooper, B.A. & Day, R.H. 1997. Radar study of seabirds and Bats on Windward Hawai'I. *Pac. Sci.* **51:** 97–106.

Rubolini, D., Maggini, I., Ambrosini, R., Imperio, S., Paiva, V.H., Gaibani, G., Saino, N. & Cecere, J.G. 2014. The effect of moonlight on Scopoli's Shearwater *Calonectris diomedea* colony attendance patterns and nocturnal foraging: A test of the foraging efficiency hypothesis. *Ethology* **120:** 1–16.

Torres-Mura, J.C., Lemus, M.L. & Hertel, F. 2015. Plastic material in the diet of the Turkey Vulture (*Cathartes aura*) in the Atacama desert, Chile. *Wilson J. Ornithol.* **127:** 134e138.